Climate and Climate Change

Chapter 12

Learning Objectives

- **Understand the difference between climate and weather and how their variability is related natural hazards**
- **Know the basic concepts of atmospheric science, such as structure, composition, and dynamics of the atmosphere**
- **Understand how climate has changed during the past million years through glacial and interglacial conditions and how human activity is altering our current climate**
- **Understand the potential causes of climate change**
- **Know how climate change is related to natural hazards**
- **Know the ways we may mitigate climate change and associated hazards**

Global Change and Earth System Science

- **Overview of Earth System Science**
  - **Two basic goals**
    - Understand how Earth works and how it has evolved
    - Apply that understanding to better manage our environment
- **What is the Earth System Science discipline?**
  - Seeks to further understand the various components of the system; the atmosphere, lithosphere, biosphere, and hydrosphere, are linked on a global scale and interact to affect life on earth

Climate and Weather

- **Weather…**
  - **Short-run atmospheric conditions that exist for a given time in a specific area**
  - The **sum of temperature, humidity, cloudiness, precipitation, pressure, winds, storms, and other variables for a short period of time**
  - **Weather is in an almost constant state of change**

Climate and Weather

- **Climate……**
  - The **generalized variations of the weather**
  - The **aggregate of day-to-day weather conditions of a long period of time.**

    - Has **averages, variations and extremes**
- **Climate and Weather have direct and obvious influences on agriculture, transportation, and human life, and the physical land**

Climate Zones

- Based on the average annual and average monthly values of temperature and precipitation
- **Four of the five major climatic groups defined by temperature** characteristics, **fifth** is **based on moisture** characteristics
- **Five Major Climate** zones
    - **A, B, C, D, E**
- **Each Major Zone** subdivided into **14** individual climate group
- **Special category of "highland" climate**

Six Climate Zones

- **Six Major Zones**
    - **Equatorial warm-wet**
    - **Tropical hot-dry**
    - **Subtropical warm**
    - **Warm temperate**
    - **Mid Latitude cool temperate**
    - **High-latitude cold**

Climates of the World

- **Climates of the World**
    - **Humid Subtropical**
    - **West Coast Desert**
    - **Mediterranean**
    - **Desert**
    - **Equatorial Wet**
    - **Monsoon**
    - **Mountains**
    - **Steppe**
    - **Tropical Wet-Dry**
    - **Humid Continental**
    - **Marine West Coast**
    - **Continental Subarctic**

- **Arctic**
- **Ice Cap**

Earth Climate System and Natural Processes

- Climate exerts a major influence on natural processes
- Becoming familiar with earth's climate zones is a first step in recognizing the treat from natural hazards
- Applying classification provides not only a map of the world climates but also information about the relationship between climate and vegetation

The Atmosphere

- Atmospheric Composition
  - Permanent gases – gases which are in a constant proportion of the mass of the atmosphere
  - Nitrogen and oxygen
  - Variable gases – gases whose proportions vary in time and space
  - Carbon Dioxide
  - Aerosols – microscopic particles whose proportions also vary in time and space
  - Dust

Permanent and Variable Gases

- Permanent Gases
  - **Nitrogen and Oxygen make up the 99 % of the atmosphere**
  - 78% Nitrogen
  - 21% Oxygen
  - Other 1%
  - Argon .9%
  - Carbon Dioxide .038%
  - All other gases .06% equaling .998%

Gaseous Composition of Dry Air
Particulates (Aerosols)

- **Large nongaseous particles** are in the atmosphere
- **Mainly liquid water and ice**
    - **Clouds, rain, snow, sleet, and hail**
- **Dust particles large enough to be visible**, but too heavy to fall to the ground
- **Smaller particulates are invisible to the naked eye**, may also be suspended in the atmosphere
- **Found near their origin, either urban areas, or the natural condition that caused the particulate**

Glaciations

- A study of climate change can be thought of as **a study of changes in the atmosphere and the linkage with the cryosphere**
- The **cryosphere is a part of the hydrosphere that stays frozen all year round**
- Major components of the **cryosphere include permafrost, sea ice, ice caps, glaciers, and ice sheets**
- **Ice in permafrost, sea ice, and ice caps are either fixed in place or floating**
- **Glaciers form an ice sheet, flow from high areas to low areas under the weight of the accumulated ice.**
- Like **beaches, glaciers and ice sheets have budgets with inputs and outputs**
- **Pleistocene Glaciation**
    - Over the **past 3.2 million years, earth's climate system has fluctuated greatly, alternating between *glacial intervals***
    - **About 2.5 million years ago- there was an "amplitude" in climate fluctuations- causing some parts of the Northern Hemisphere to be covered by glaciers**
    - The **last major glacial period in North America known as the "Wisconsin" glacial stage ended approximately 10,000 years ago**
    - Scientists believe that **we are presently in a interglacial period with the highest temperatures since the last interglacial interval some 125,000 years ago.**

Effects of Pleistocene Glaciation

- **Periglacial processes-** the erosion & deposition done by the prodigious amounts of melt water released as the glaciers melted
- Frost weathering associated with solifluction of frozen subsoil
- **Sea-level Change-** more water stored in the ice – less water in the oceans – when glaciers melted ocean levels went up
- **Crustal depression-** enormous weight of accumulated ice on continents caused portions of Earth's crust to sink- When ice melted the crust would rebound- Isotactic adjustment in portions of Canada and Europe- These areas are still rising
- **Pluvial (increased rain) developments -** during glaciation period There was a considerable increase in precipitation, and a decrease in evaporation
  - Result 'pluvial effects' created many lakes where previously there had been none
  - Most have drained or significantly reduced in size but have left lasting imprint- example Lake Bonneville

Glaciations Past

- At maximum Pleistocene extent, ice covered one third of the total land area of Earth
- The period since then is known as the "Holocene" epoch. Could be either post glacial or an interglacial interlude

Contemporary Glaciation

- **Compared to Pleistocene glaciation, the extent of ice covering the continent surfaces today is very small – 96% in Antarctica and Greenland**

Glacial Hazards

- Glacier may look fairly harmless, but they are huge actively flowing masses of ice and rock debris
- They are responsible for property damage, injuries, and deaths.
- When glaciers move into the ocean, huge chunks of ice fall in the water in a process known as *calving*
- These chunks of ice are known as *icebergs* creating a hazard in navigation for large ships.
  - ***The most famous ship to hit an iceberg would be the Titanic***
- Volcanos with glaciers on them, erupt causing the glaciers to melt causing large

amounts of water and debris to flow down with the lava

How We Study Past Climate Change and Make Predictions

- There are three different kinds of data being gathered to help understand the changes in the earth over time
- These are:
- **Instrumental Records** – recording of temperatures in both the ocean and on land since 1860
- **Historical Records** – a variety of records going back several hundreds of years, including people's written recollections (books, magazines, journal articles) of the Medieval Warming Period and the Little Ice Age Ship's logs, traveler's diaries, and farmers crop records
- **Paleo-proxy Records** – the study of the earth climate or Paleoclimatology which is a part of earth science These records provide the strongest data to support the earth's past

Paleo-Proxy Records

- **Paleo-proxy data** includes not only analytic climate data but also information that shows differences in the climate over time. This kind of data analysis includes:
- **Dendroclimatology** – study of the tree rings from different trees over time to show the climate through the tree growth.
- **Oxygen Isotope Analysis of Oceanic Sediments --** study of the sediments found under the sea and ocean. These sediments come from the soil and plants of the past.
- **Ice Cores** -- Analysis of the chemicals and materials found in the ocean waters and ice. Drilling cores from the bottom of the ocean helps to explain the climates of the past.
- Paleo-proxy data includes not only climatic data but also information that shows differences in the climate over time. This data includes:
- **Pollen Analysis (palynology)** -- Using radiocarbon dating on pollen and dust matter found in sediment layers helps to identify how climates have changed over time
- **Corals –** Coral reefs consist of corals with hard skeletons composed of calcium carbonate. This calcium contains isotopes and traces of metals which can

help to define the past climate

- **Carbon 14** – Records the solar flares of the past. Combined with tree ring dating helps scientists tell the history of the change in climate
- **Carbon Dioxide** – The amount of carbon dioxide in the atmosphere is one of the most important measurement of the climate change

Climate Change Models

- **Scientists have developed mathematical models to represent real-world climate change**
- These are called models were first developed in the 1950's, are now called the ***Global Warming Models***
    - These models showed the linkages and interactions between natural processes to predict the flow of surface water and groundwater, erosion, and deposition of stream sediment, and global circulation of water in the ocean and air in the atmosphere
    - Models were run backwards to see if they accurately describe historic and prehistoric climate change
    - Doing this helped to verify that using these models to predict future climate change
    - These models now are used to show the global temperature change from 1900 to the present
    - These models are used to try develop and approach to solve the complex problems of climate change
    - The problem with trying to use the models is predicting what people are going to do.
    - Today these models provide useful guidance on regions that are likely to be relatively wetter or drier and hotter or colder in the future
    - These models are to measure the past 150 years climates to better understand and predict the future climates

Global Warming

- **Global Warming** is defined as the observed increase in the average temperature of the near-surface land and ocean environments of the earth during the past 50 years.
- The Greenhouse Effect –
    - The temperature of the earth is determined by **three factors**:

    - **<u>The amount of sunlight the earth receives</u>**
    - **<u>The amount of sunlight the earth reflects, therefore does not absorb</u>**
    - **<u>The atmospheric retention of reradiated heat</u>**
  - This is the ***earth's energy balance*** is slightly out of equilibrium, more energy coming in from the sun than is reflected back out into space

- **<u>Global Energy Budget</u>**
  - **100 units of Solar Radiation hits the atmosphere**.
    - Some absorbed
    - Some reflected
    - Some radiated
  - **Total units radiated out 100 units**
- Solar radiation are **short waves**, where terrestrial radiation are **long waves**
- When the solar radiation **short waves hit the earth, they are absorbed into the earth's surface and then it is radiated out in long waves**
- The **<u>atmosphere is heated by *Earth radiation*</u>** rather than the sun radiation.

- **<u>Greenhouse Warming</u>**
- This warming of the **<u>atmosphere from terrestrial warming has been going on for millions of years</u>**
- But with the addition of the **<u>water vapor, chemicals, and gases</u>** we are adding to the atmosphere the **<u>terrestrial LONG waves</u>** from the earth can not escape the **atmosphere** and they become **trapped close to the earth**
- **<u>Example</u> – when you sit in a car with the windows rolled up on a sunny day, the solar radiation short waves easily shines in through the windows and are absorbed into interior of the car. The interior of the car now radiate out long waves, as if it were terrestrial waves. These will not pass through the windows (the atmosphere), making the inside of the car extremely hot!**

- **Global Temperature Change**
  - Since the Pleistocene ice ages, 2 million years ago, there have been numerous changes in the earth's mean temperature.
  - During these changes the temperature has either increased or decreased.
  - Does that mean the earth has gone through many global warmings or coolings?
- **Why Does Climate Change**
  - **<u>Milankovitch cycles</u>** reproduce long-term cycles observed in the climate

- These are after Milutin Milankovitch, the scientist who discovered them
- These cycles force (push) the climate in one direction or another, can be looked at as natural process that when linked to other processes, produce climate change
- There are cycles of climate change which can last up to 100,000 years or shorter cycles last between 20,000 to 40,000 years
- These cycles **force (push)** the climate in one direction or another which can be looked at as natural processes when with linked other processes. They produce some climate change but not enough be responsible for large-scale global climatic changes
- **These cycles combined with other processes must be invoked to explain global climatic change**
- **Scientists now believe the climate system may be inherently unstable and capable to changing from warming to cooling quickly**

- Although scientific uncertainties exist, sufficient evidence exists to state that:
  - There is a **discernible human influence on global climate**
  - **Warming is now occurring**
  - The mean **surface temperature of the earth will likely increase by between 2.6 degrees to 7.8 degrees F during the twenty-first century**

- Now to better understand global warming we will look at the major forcing variables that influences this warming
  - **Climate Forcing**
  - **Solar emission**
  - **Volcanic eruption**
  - **Anthropogenic input**

- **Climate Forcing**
  - Part of what may drive the climate system and its potential change is the ***ocean conveyor belt***, a global-scale circulation of ocean waters, characterized by strong temperature change northward movement near -surface water in the Atlantic Ocean that are cooled when they arrive near Greenland.
  - As the water cools, it becomes saltier; the salinity increases the water's density and causes it to sink to the bottom
  - The current then flows towards Africa where it is added to a huge warm water belt and it is warmed.
  - If this conveyor belt were to shut down there would be an effect in the climate

of Europe would cool

- **Solar Forcing**
  - Since the **sun is responsible for heating the earth, a solar variation should be evaluated as a possible cause of climate change**
  - In the history of climate during **the past 1000 years, the variability of solar radiation plays a role in these changes**

- **Volcanic Forcing**
  - When v**olcanoes erupt they hurl vast amounts of particulate matter into the atmosphere**
  - This matter can affect the **current weather and the overall climate of the earth**
  - These eruptions can **add uncertainty in predicting global temperatures**

- **Anthropogenic (human activity) Forcing**
  - Evidence of anthropogenic climate forcing, resulting in a warmer world, is based in part, based on the following
    - Recent warming over the past few decades **cannot be explained by natural variety of the climate over recent geologic history**
    - **Industrial age forcing is mostly due to emissions of carbon dioxide that, with other greenhouse gases, have greatly increased in concentration in the past few decades**
    - Climate models suggest **that natural forcings in the past 100 years cannot be responsible for what we know to be a rise in global land temperature.**

Potential Effects of Global Climate Change

- A summation of this discussion on climate change is:
  1. **Human activity is increasing the concentration of greenhouse gases in the atmosphere**
  2. **The mean temperature of the earth increased by 1.4 degrees in the past 100 years**
  3. **A significant portion of the observed increase in the mean temperature of the earth results from human activity**
     - **All climate models are consistent in predicting that warming will continue, as a result of the greenhouse gases now in the atmosphere**

and possibly accelerate in the coming decades

- **Glaciers and Sea Ice**
  - It is believed that global warming is resulting in an accelerated melting of the glacial ice found in Greenland and in mountain glaciers
  - The melting of the mountain glaciers is important to the people who depend on water from these glaciers and the ecosystem dependent on these glaciers
  - The Arctic ice is predicted to soon have a time where there will be a seasonal ice free cycle
- **Positive effects of global warming on glaciers and sea ice**
  - In Antarctica, there is a positive effect happening because of global warming
  - It is predicted that due to global warming, Antarctica will receive more snow than usual in a year. This will build up the ice cap instead of depleting it.
- **Climate patterns**
  - Global warming might change the frequency and intensity of violent storms as warming oceans feed more energy into the atmosphere
  - More coastal storms will increase the hazard of living in low-lying coastal areas, many which are experiencing rapid human growth

El Nino- Southern Oscillation

- **El Nino** -- An episodic atmospheric and oceanic phenomenon that happens in the Pacific Ocean every few years, the last occurrence was in 1997-98
  - Abnormally warm water appears at the surface of the ocean off the west coast of South America
  - Can cause increased rains in northern hemisphere, less fish off the coast of South America, and drought in Southeast Asia
  - Causes not totally understood
  - In the 1997-98 occurrence, there was flooding, droughts, and wildfires
- **La Nina** in which the eastern Pacific waters are cool, and droughts, rather than floods, may result in Southern California

Other Multi-Year Atmospheric and Oceanic Cycles

- **Pacific Decadal Oscillation**
  - Approximately every 20 to 30 years sea surface temperatures change in the northern/west tropical and eastern tropical Pacific Ocean causing

atmospheric changes around the world

- **The North Atlantic Oscillation (NAO) and Arctic Oscillation**
    - The NAO – irregular "seesaw" of pressure differences between two regional components of the general atmospheric circulation of the Northern Atlantic basin
    - Arctic Oscillation alternates warm and cold phases as in the NAO.

Sea-Level Rise

- The rise in sea-level is a potentially serious problem related to global warming
- The ocean waters are warming due to global warming
- **Conclusions from this rising can be made, these are**
    - Both thermal expansion and melting glacial ice contribute to the observed seal-level rise since 1961
    - The difference between the observed and estimated rise in sea level is considerable, suggesting that additional research is need to better understand sea-level rise
    - The rates of both thermal expansion and melting glacial ice are accelerating
    - The Greenland ice sheet's contribution to sea-level rise has increased about 4 times in recent decades, consistent with surface observations of melting glacial ice (DUH!)

Wildfires

- There is a **complex relationship between climate change and fires (wild)**
- The two phenomena interact on a variety of levels
    - Global warming is predicted to lead to an increase to both droughts and El Nino events
    - This will set the stage for more wildfires due to droughts
    - The prediction models used in climate change show that there will be more frequent and severe forest fires in a given area, with the number of years between these events will decrease

Changes to the Biosphere (animals and plants)

- A growing body evidence indicates that global warming is initiating a number of changes in the biosphere, threating both ecosystems and people
- These impacts on ecosystems are:
    - Climate change may be accelerating

    - Warming is expected to be 3.6-7.2 degrees
    - Precipitation in some regions is projected to be less frequent but more intense
    - The temperature of streams and rivers will likely increase
    - Wildfires will be more frequent
    - Growing season will lengthen, with earlier spring and greater primary productivity, especially at higher latitudes
    - Rainfall and wind speed from hurricanes and other violent storms are likely to increase as warming continues
    - The oceans are warming and becoming more acidic
- As a result:
- Some species will experience stress, most vulnerable will be those that are not mobile, such as some vegetables on land and shellfish in the ocean
- Many species will migrate toward higher altitudes in a attempt to adapt to warming

Adaptation of species to global warming

- There have be evaluations of the potential threats to species or their possible regional extinction, simple models were primarily used to calculate conclusions
- Newer models are now being used with better information, to help determine how to proceed
- There has been a controversial suggestion that man help with the migration of some species to help them adapt to the warming.
- There are some pros to this thought, but there are more cons to it
- More research needs to be done before we step in and help with a migration

Predicting the Future Climate

- Predicting the future climate is problematic as is predicting the future. **You could be WRONG!!!**
- For climate and its effects on living things, we can attempt to apply the geological concept of *uniformitarianism*, which assumes
    - That processes that occurred in the past occur to and will occur in the future
    - Scientists are trying to look into the past to see the climate to predict the future
    - The only problem is there have only been records of temperature for the

past 150 years. Before that there are none

- With all our new technology, we can begin to keep records and models, but they really don't tell us where we are going without knowing the past

Strategies for Reducing the Impact of Global Warming

- The big question being asked now is: What is the origin of rapid climate change over decades to about 100 years that we believe has happened during geologic time (past 1,000,000 years)?
- Two other important questions are:
  - What changes have occurred?
  - What changes could occur in the future?
- We (man) now know that there is an increase in global warming due to greenhouse gasses.
- We as humanity felt the world's countries and leaders needed to come together in an effort to reduce the production of these gases and address global warming

- There have been several joint agreements between the countries of the world to try and decrease the amount of greenhouse gasses produce.
- **The United States joined these agreements but as of 2005, we have withdrew from the organizations**
- Our **Congress have chosen to filibuster legislation that would regulate the amounts of greenhouse gases added to the atmosphere**
- Many **different studies and programs have been developed and are being tried to reduce the "carbon footprint" of the US**
- There have been studies which indicate **global warming is not as urgent a problem as first thought, but looking ahead to the end of the 21st century, the human suffering that might result in a harsh climate change, when there are 9 to 10 billion more people on earth to feed**